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Testing the Two-Layer Model for Correcting Clear Sky Reflectance Near Clouds

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Executive Summary

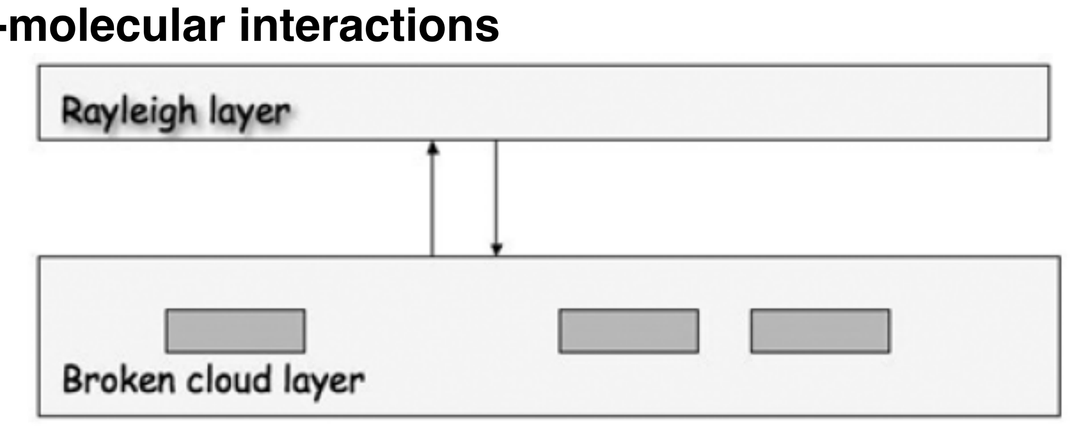
A two-layer model (2LM) was developed in our earlier studies to estimate the clear sky reflectance enhancement due to cloud-molecular radiative interaction at MODIS at 0.47 µm. Recently, we extended the model to include cloud-surface and cloud-aerosol radiative interactions. We use the LES/SHDOM simulated 3D **true** radiation fields to test the 2LM for reflectance enhancement at 0.47 µm. We find:

- The simple model captures the viewing angle dependence of the reflectance enhancement near cloud, suggesting the physics of this model is correct.
- The cloud-molecular interaction alone accounts for 70% of the enhancement.
- The cloud-surface interaction accounts 16% of the enhancement.
- The cloud-aerosol interaction accounts for additional 13% of the enhancement.

We conclude that the 2LM is simple to apply and unbiased.

Two-Layer Model

1. Cloud-molecular interactions

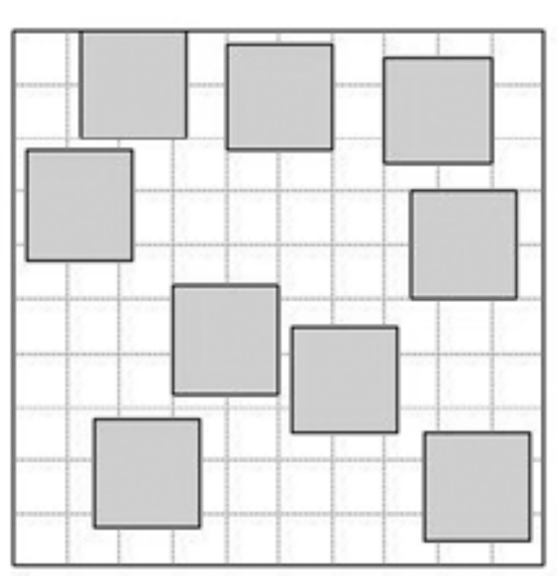


ΔR = radiance reflected from broken cloud field with a scattering Rayleigh layer above it **minus** that purely due to extinction (non-scattered).

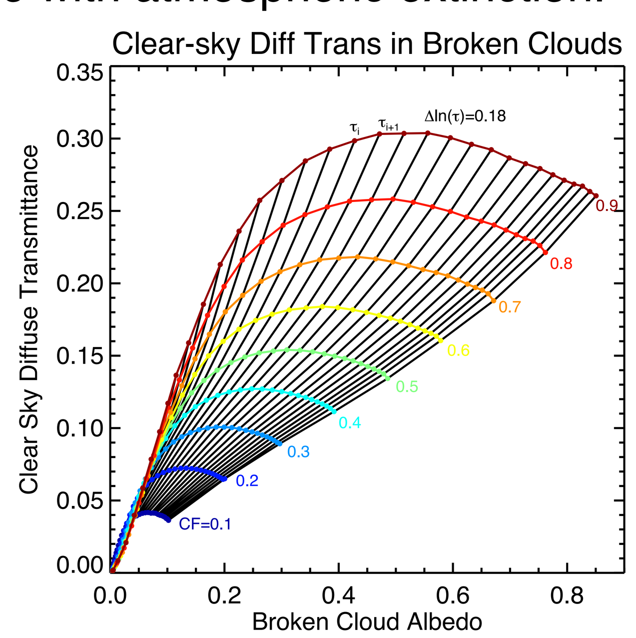
2. Cloud-surface interactions

We use a fast Monte Carlo scheme for Poisson model of broken clouds to compute 3D cloud induced diffuse flux. The cloud-surface induced enhancement is the surf leaving radiance with atmospheric extinction.

CF = 0.3
Cloud aspect ratio of 1



Marshak, et. al., 2008



Left: an example of the Poisson distribution of broken cloud field
Right: clear sky diffuse transmittance as a function of cloud albedo for cloud aspect ratio of 2, SZA=36

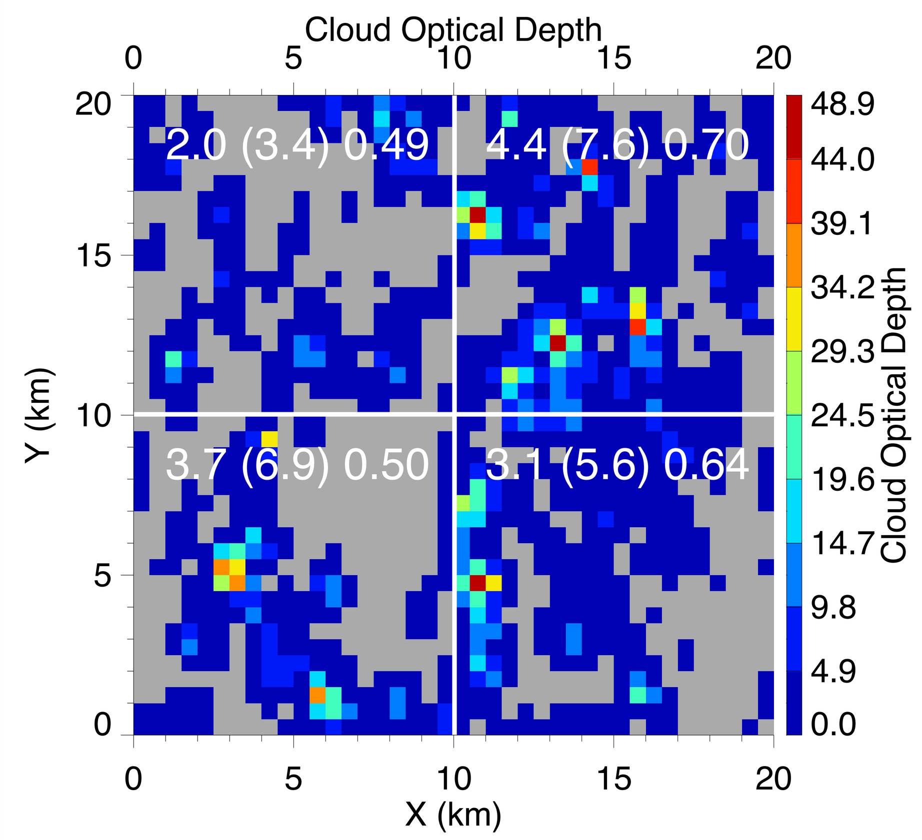
3. Cloud-aerosol interactions

We introduce an *effective* molecular optical depth that includes aerosols $\tau_{m,eff} = \tau_m + \varepsilon\tau_a$ for the 2LM, where ε depends on scattering phase function and single scattering albedo. For given aerosol optical depth in LES data, we find ε empirically such that the total error in 2LM is nearly zero.

SHDOM Simulations

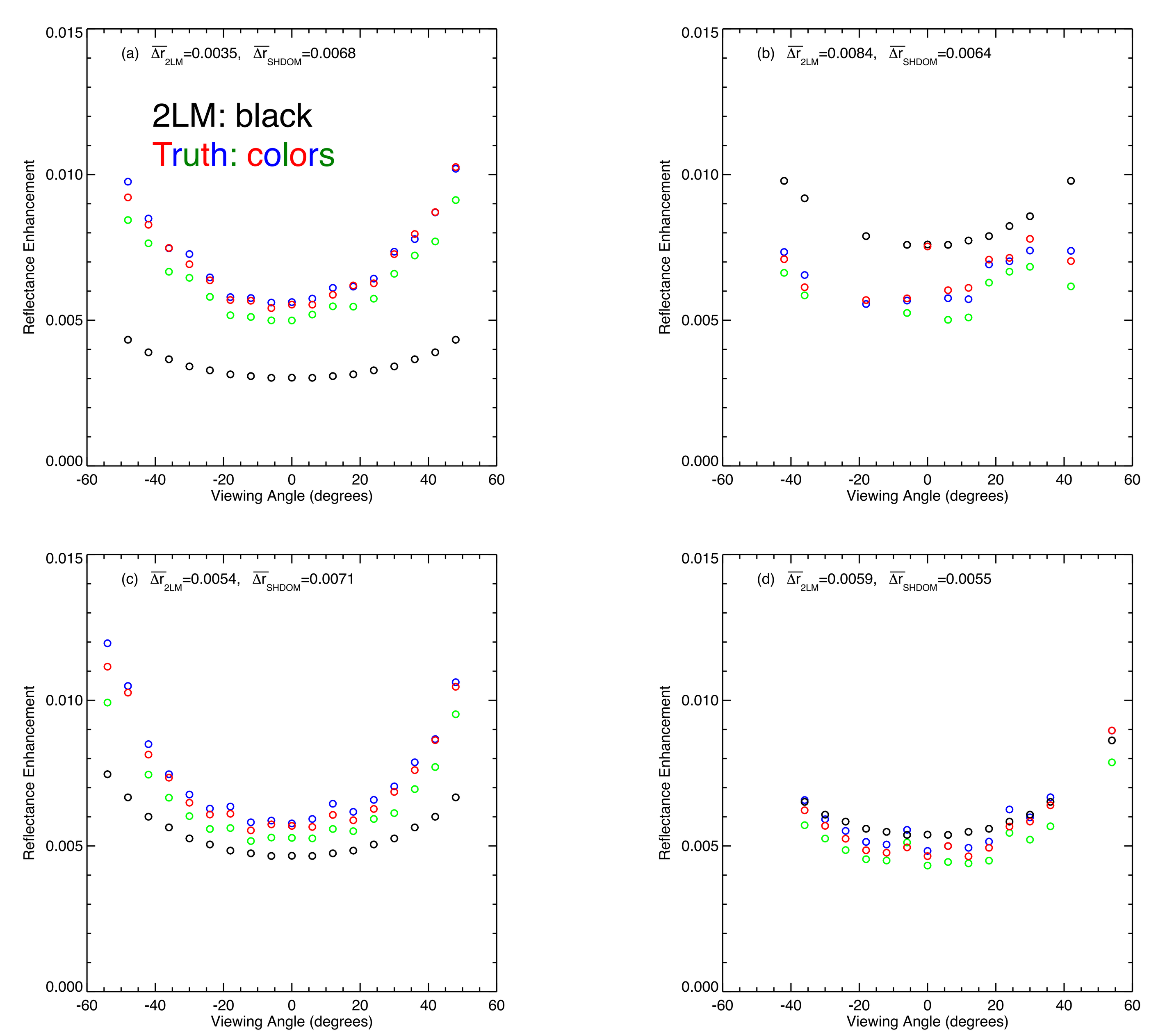
- 26 fields (cloud liquid water content and relative humidity) were simulated using the UCLA large eddy simulation (LES) model
- Combined 26 LES cumulus fields with 40 GEOS-5 aerosol profiles to make 80 cloud/aerosol scene (20 km x 20 km x 15 km).
- Radiances were simulated using SHDOM at 500 m MODIS resolution with 23 viewing direction appropriate for MODIS Aqua.
- MOD04 cloud masking procedure is applied to select "good" pixels. There are 100188 "good" pixels in all 80 cloud scenes, and number of "good" 10 km x 10 km boxes is 3154.

Viewing Angle Dependence

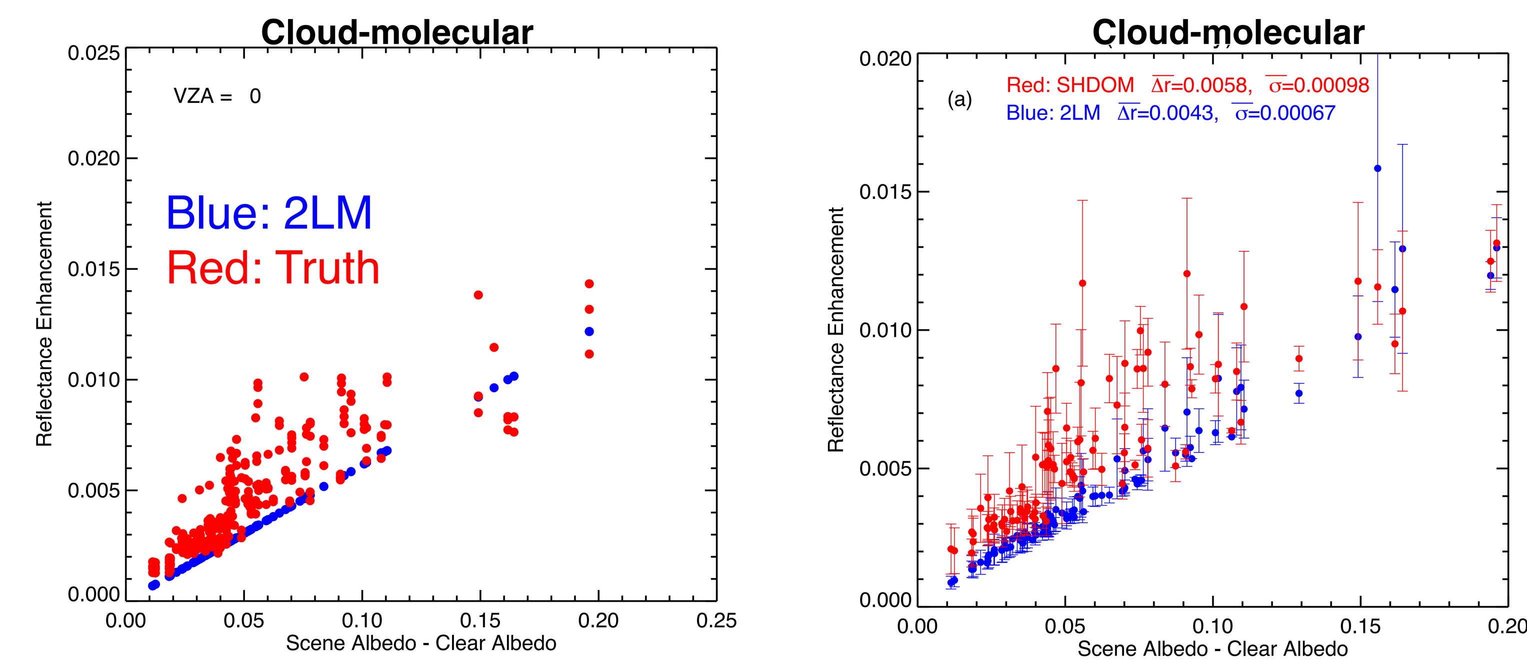


Left: LES simulated cloud optical depth field with mean (standard deviation) and cloud fraction indicated.

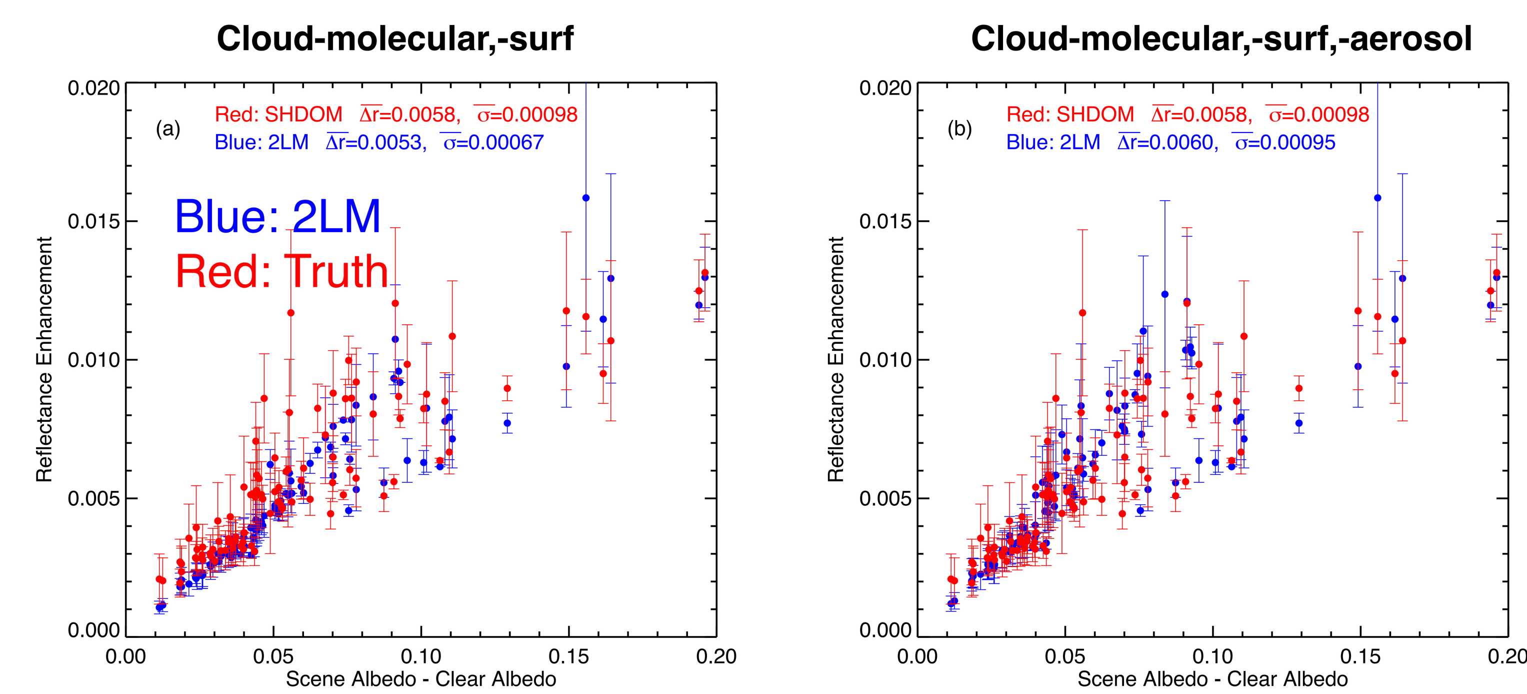
Below: The 2LM (black) captures the viewing angle dependence of the truth. Though the error for each individual box can be large (50%), on the average, the error is about 20%.



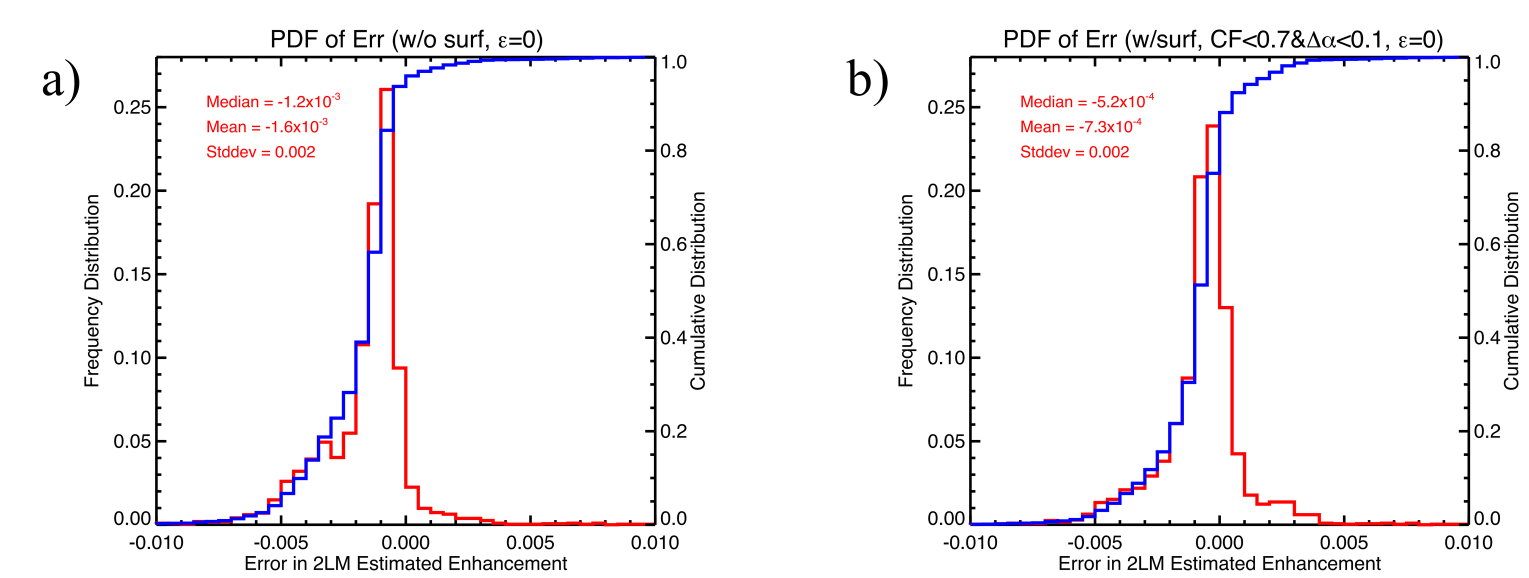
Compare 2LM with Truth

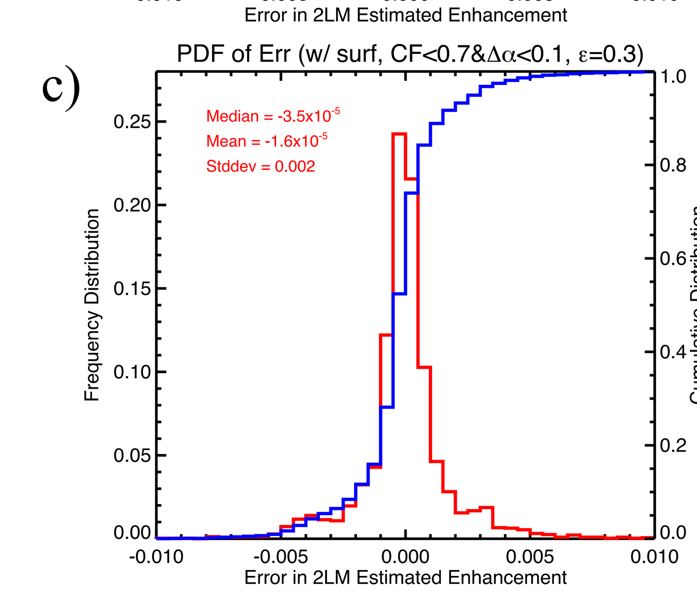


Left: Compare the 2LM (cloud-molecular interactions) with the truth for given VZA.
Right: Similar to the left but for all data points. The averages and standard deviations are presented. The 2LM underestimate the truth by 25%



Left: Compare the 2LM (cloud-molecular and cloud-surface interactions) with the truth. 2LM underestimates by 9%.
Right: Similar to the left but 2LM accounts for cloud-mole, cloud-surf, and cloud-aerosol interactions. 2LM overestimates by 3%.





a) PDF and cumulative distributions of 2LM error for cloud-mole interactions. The 2LM accounts for 70% of the enhancement.
b) 2LM that includes cloud-mole and cloud-surf accounts for 86% of the enhancement.
c) 2LM that includes cloud-mole,-surf,-aerosol accounts for 99% of the enhancement.